

REMARKS

Favorable reconsideration of this application as presently amended and in light of the following discussion is respectfully requested.

Claims 26-47 and 49 are pending in the present application. Claims 26, 44, and 47 are amended and Claims 48 and 50 are canceled without prejudice by the present amendment.

In the outstanding Office Action, Claim 47 was objected to; Claims 26-50 were rejected under 35 U.S.C. § 112, second paragraph; Claims 26-45 and 47-49 were rejected under 35 U.S.C. § 103(a) as nonobvious over Whitehead (International application WO 200169285 A1) in view of Nam (U.S. Patent No. 5,527,565); Claim 46 was rejected under 35 U.S.C. § 103(a) as unpatentable over Whitehead, Nam, and Jones (U.S. Patent No. 5, 216,249); and Claim 50 was rejected under 35 U.S.C. § 103(a) as unpatentable over Whitehead, Nam, and Cotty (U.S. Patent No. 6,806,145).

The specification has been amended to correct an informality on page 3, fourth full paragraph. More specifically, the term “electric field” has been replaced by “biasing voltage,” which is consistent with the units (V) of the value of the biasing voltage stated in the same paragraph and also with at least Claim 33. In addition, Claim 44 has been amended to correct a minor informality. No new matter has been added.

Regarding the objection to Claim 47, Claim 47 has been amended to be in independent form as suggested by the outstanding Office Action and to recite various characteristics of a high purity crystal, as disclosed in the specification, for example, at page 4, last two full paragraphs and at page 5, first three full paragraphs. No new matter has been added. Accordingly, it is respectfully requested this objection be withdrawn.

Regarding the rejection of Claims 26-50 under 35 U.S.C. § 112, second paragraph, Claim 26 has been amended to recite various features that characterize a high purity single

crystal CVD diamond, as disclosed in the specification, for example, at page 4, last two full paragraphs and at page 5, first three full paragraphs. No new matter has been added. In addition, Claims 48 and 50 have been canceled without prejudice. No new matter has been added. Accordingly, it is respectfully requested this rejection be withdrawn.

The remaining rejections on the merits are respectfully traversed in view of the amendments to independent Claims 26 and 47, as discussed next.

Briefly recapitulating, amended Claim 26 is directed to a method of detecting radiation. The method includes, inter alia, providing a layer of high purity single crystal CVD diamond having at least one of (i) in an off state, a resistivity R_1 greater than $1 \times 10^{12} \Omega \text{ cm}$ measured at an applied field of $50 \text{ V}/\mu\text{m}$ and 300 K, (ii) a $\mu\tau$ product greater than $1.5 \times 10^{-6} \text{ cm}^2/\text{V}$, measured at an applied field of $10 \text{ V}/\mu\text{m}$ and 300 K; (iii) an electron mobility (μ_e) measured at 300 K greater than $2400 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$; (iv) a hole mobility (μ_h) measured at 300 K greater than $2100 \text{ cm}^2\text{V}^{-1}\text{s}^{-1}$; and (v) a high charge collection distance greater than $150 \mu\text{m}$, measured at an applied field of $1 \text{ V}/\mu\text{m}$ and 300 K.

The method of Claim 26 advantageously detects radiation with a high purity single crystal CVD diamond that saturates at a low applied field of no greater than $0.5 \text{ V}/\mu\text{m}$.

Turning to the applied art, Whitehead discloses a detector having a layer of boron-doped diamond, which acts both as a support and a contact material, and a layer of undoped CVD diamond grown on top of the boron-doped diamond layer. The layer of CVD diamond in Whitehead does not have any of the claimed characteristics added to Claim 26.

Further, there is no suggestion in Whitehead that a saturation electric field (that is the electric field at which the charge collection efficiency stops increasing with an increase in the electric field) might be lower than about $1 \text{ V}/\mu\text{m}$. In this regard, Applicants respectfully submit that because Whitehead does not make any reference to the saturation electric field, one of ordinary skill in the art would consider the saturation electric field to be that known in

the art at the time the invention was filed, e.g. the saturation electric field disclosed in Bauer et al., Nuclear Instruments and Methods in Physics Research A, 367 (1995) 207-211. Bauer et al. shows that the saturation of the electric field for diamond is about 10 kV/cm (that is, 1 V/ μ m). This status of the saturation electric field in the art is also consistent with the disclosure of the reference cited in the last paragraph on page 1 of the specification.

Further, Whitehead discloses obtaining large grains of material suitable for use as a detector. However, the diamond material in Whitehead is not high purity single crystal CVD diamond, as defined by amended Claim 26. Furthermore, there is no suggestion in Whitehead that the use of high purity single crystal CVD diamond would allow detection of radiation at low applied fields and hence low voltages.

In addition, Applicants respectfully submit that to their knowledge, prior to filing the present application, there were no reports in the published literature of a diamond being used as a detector and being able to operate with a low electric field between the electrodes.

The low applied field together with the high charge collection distance of the high purity single crystal CVD diamond result in the operating voltage of the detector being lower than it is possible with conventional diamond detectors. Because a detector operating at a high voltage is dangerous and expensive, the claimed device solves these problems by operating at a substantially lower voltage.

The advantages of the claimed detector are discussed next after providing a brief explanation of how detectors work. Radiation detectors work by the interaction of the radiation with the solid (of the detector) to generate electron-hole pairs. The electron-hole pairs are separated by the applied field and charges are generated on electrodes at the surface and quantified by an external circuit. The rate at which the electron-hole pairs are generated by radiation is dependent upon the type of radiation, the less the interaction with the solid, the fewer electron-hole pairs are generated. As an example, gamma rays interact with matter

weakly and generate few electron-hole pairs per unit length of matter traversed, whereas alpha particles interact strongly and generate large numbers of electron-hole pairs per micron of matter traversed. Whatever type of radiation the detector is intended to detect, the radiation flux required to constitute a signal determines the sensitivity of the detector. When comparing detectors, the same type of radiation should be used for the detectors.

An example is next provided to illustrate how two detectors should be compared. For example, a quantity Minimum Ionizing Particles (MIPs) is being detected. MIPs interacts weakly with the diamond, generating approximately 36 electron-hole pairs per μm of diamond traversed. A detector can detect individual MIPs. An event is a single MIP traversing the detector. The detector is connected to a charge sensitive amplifier which may require a minimum input charge (typically equivalent to about 7000 electrons or about 10^{-15} Coulombs).

These factors are compared in the following table and the thickness of a detector based on these factors and the voltage to be applied to the detector to detect the same amount of charges are also shown. This comparison is estimated for a detector having the features of Claim 26 and a detector as in Whitehead. It is noted that the input numbers provided in the table are exemplary only and not intended to limit the claims to such values.

	Device with high purity single CVD diamond	Device with no high purity single CVD diamond
Charge Collection Efficiency of material, %	>95	60. maximum
Number of electrons (or holes) that must be collected to unequivocally detect an event	7000	7000
Number of electrons (or holes) that must be generated to ensure sufficient are collected	$7000/0.95 = 7370$	$7000/0.60 = 11670$
Thickness of material needed to generate sufficient holes	$7370/36 = 205 \mu\text{m}$	$11670/36 = 325 \mu\text{m}$
Saturation electric field	$0.2 \text{ V}/\mu\text{m}$	$1 \text{ V}/\mu\text{m}$
Operating Voltage = Thickness x Applied Electric Field	$205 \times 0.2 = 41 \text{ Volts}$	$325 \times 1 = 325 \text{ Volts}$

Thus, it can be seen from the above example that the high purity single crystal CVD diamond can be operated at a considerably lower voltage and is thinner than other detectors that do not use the high purity single crystal CVD diamond.

The outstanding Office Action relies on Nam for teaching a CVD diamond layer being a single crystal CVD diamond. However, Nam does not cure the deficiencies of Whitehead discussed above with regard to Claim 26, because Nam does not teach or suggest a high purity single crystal CVD diamond.

Jones and Cotty have been considered but none of these references cures the deficiencies of Whitehead and Nam discussed above with regard to independent Claim 26.

Accordingly, it is respectfully submitted that amended Claim 26 and each of the claims depending therefrom patentably distinguish over Whitehead and Nam, either alone or in combination.

Consequently, in light of the above discussion and in view of the present amendment, the present application is believed to be in condition for allowance and an early and favorable action to that effect is respectfully requested.

Respectfully submitted,

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